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Openness and Technology Diffusion in Payment Systems: The Case of NAFTA*

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Abstract

We study the relationship between openness and payment system development. In particular, we analyze how the existence of technology diffusion from a more developed country fosters a transformation of payment choice in a less developed country. We apply our analysis to Mexico. Economic growth in Mexico was not high enough to cause a transformation of payment choice observed in the data after 2001. We argue that the switch towards electronic payments can be attributed to openness and related payment technology spillovers from the US in the context of NAFTA.

Keywords: cash; payments; openness; NAFTA.

JEL classification: E42, F43, O33, O54.

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1 Introduction

Economic growth can generally explain a transformation of payment choice over time. Growth in Mexico, however, was not high enough to cause a switch from cash towards electronic means of payment observed in the data after 2001. We argue that the switch towards electronic payments can be attributed to openness and related payment technology spillovers from the US in the context of NAFTA.

The way in which economic transactions are settled, or paid, depends on consumers' and merchants' decisions and on the availability of alternative payment methods. The continuous evolution of information technology has led to a significant transformation of payments industry giving economic agents the possibility of choosing among a greater number of payment arrangements (Evans and Schmalensse, 2009). Further, the adoption of new payment instruments, and e-money in particular, contributes to cash substitution and the development of more efficient payment and banking systems (Stojanovic, 2001). Financial and banking development is not globally homogeneous. Accordingly, the distribution and evolution of payment instruments use is usually very different across countries, even within developed ones (see Callado and Utrero, 2004). Humphrey et al. (1996) highlight that institutional and cultural differences (income, new payment instruments, etc.) modify the use of cash. Together with these, the degree of economic development is one of the main factors that positively affect the use of electronic means of payments, see for example Ireland (1994), Hromcová (2008) or Humphrey (2010).

At the same time, openness to international exchange is claimed to contribute to countries' dynamic performance, Grossman and Helpman (1991), McGrattan and Prescott (2009), among others. Recent literature has focused on additional possible implications of trade integration: an increase in the number of tradable goods (Kehoe and Ruhl, 2009), production sharing (Burstein et al., 2008), more correlated business cycles (Bejan, 2011), or increased foreign direct investment (Schulz, 2006). In the same vein, international free trade agreements, as promoters of commercial exchanges and trade, are widely accepted to be a relevant channel to technology diffusion (Zhu and Nam Jeon, 2007). Coe et al. (1997) and Schiff and Wang (2003) provide evidence that trade is an important mechanism through which knowledge and technological progress are transmitted across countries. This is specially true for developing countries that can learn from the knowledge embedded in the inputs they import. In addition, an increase in trade fosters demand for payment instruments, since any commercial relationship encompasses a wide variety of counterparties, transactions and payments (BIS, 1999). Therefore, the way transactions are paid may change not only operations among the countries participating in these commercial areas, but also within country deals. Methods of payment of the latter can modify due to the availability of new payment methods. This may be especially true for less developed countries entering into a free trade agreement with more developed economies. In this case, the use of electronic payments would enjoy a reliable and secure infrastructure, extended to the less developed economy, and allow consumers to use it (Litan and Baily, 2009). The purpose of this

paper is to study the relationship between trade openness and payment system development. In particular, the existence of technology spillovers that fosters the switch to electronic payments that has barely been explored in the literature.

Following the above discussion, this paper models consumer choices regarding different payment instruments in the countries participating in a free trade agreement process. The North America Free Trade Agreement (NAFTA) between the United States, Canada, and Mexico, is an example. On January 1, 1994, the NAFTA entered into force. By January 1, 2008 all tariffs and quotas were eliminated. As highlighted in different reports, for example Kose et al. (2004) and CESifo (2010), the effects of NAFTA have been very important in the Mexican economy, especially in terms of trade and foreign direct investment (FDI). In Figure 1 we show the pattern of real FDI from the US into Mexico. We can observe a huge increase in FDI after the end of the 90's and in particular after 1994. We can see in Figure 2 that the growth rate of US foreign direct investment into Mexico is positively correlated with the development of payment infrastructure, measured by the growth rate of the Point-of-Sale (POS) terminals per capita.¹

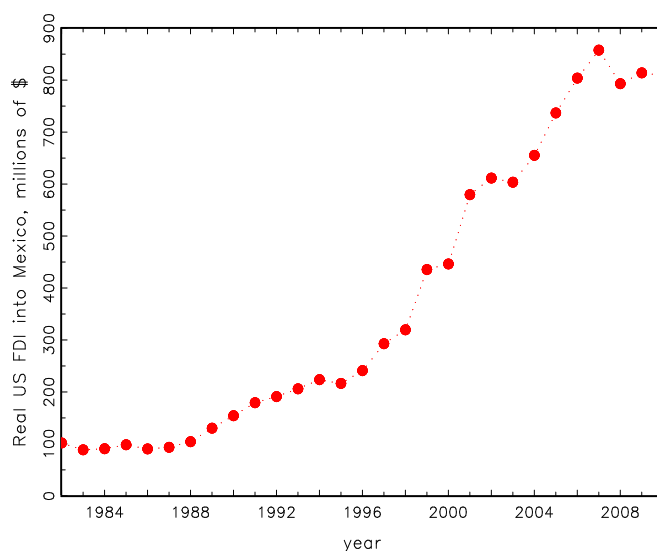


Figure 1: Evolution of US Foreign Direct Investment (FDI) into Mexico between 1982 and 2010.

¹Taking the Automated Clearing Machines (ATM) as a proxy of payment technology, instead, similar relationship is obtained between FDI and payment technology.

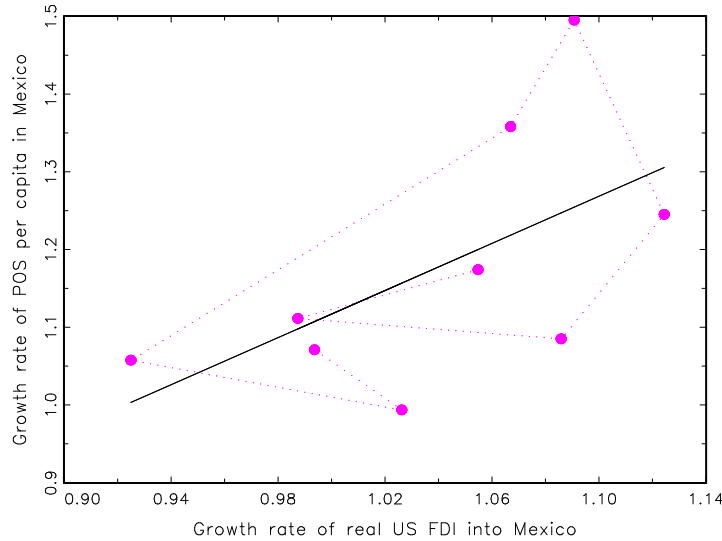


Figure 2: Correlation between the growth rate of Point-of-Sale (POS) terminals per capita and the growth rate of US foreign direct investment (FDI) into Mexico between 2001-2010.

In addition, during the start and the operation of NAFTA there appeared other shocks that might have played a role in trade and payment evolution including: a) the 1994 severe financial crisis that forced a sharp devaluation of the peso and the posterior financial sector liberalization; b) the broader global cyclical environment, which included a recovery from recessions in the early 1990s, the boom through to the end of the decade and the more recent global slump and financial crisis. However, empirical analyses suggest that Mexican banking sector efficiency did not increase significantly as a result of foreign banking acquisitions (Schulz, 2006). Moreover, data suggests that NAFTA has spurred a significant increase in merchandise trade and foreign investment flows to Mexico (Kose et al., 2004) and has led to a permanent increase in total factor productivity in Mexico's manufacturing sector through its impact on trade related technology transfers (Schiff and Wang, 2003). The development of information technology has made international transmission of knowledge faster (Jeon et al., 2005). Accordingly, technology applied to payments have evolved rapidly in Mexico. We show in Figure 3 how the number of POS terminals in Mexico with respect to the average number of terminals in all three NAFTA countries increased sharply after the trade agreement started to operate.

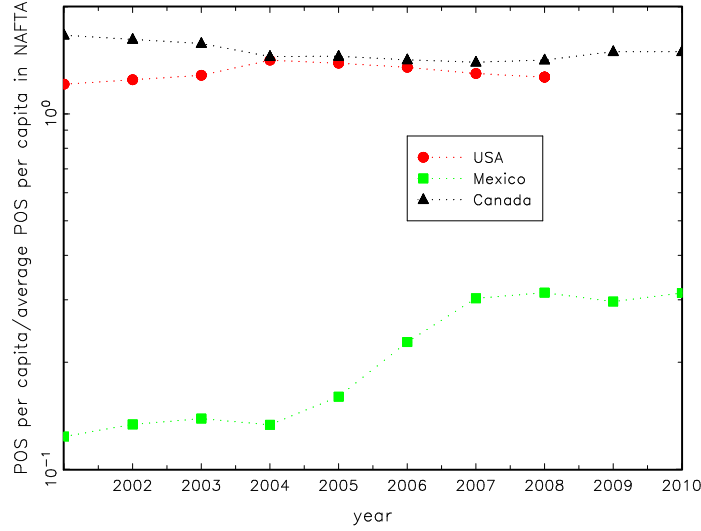


Figure 3: Evolution of Point-of-Sale terminals per capita in the USA, Mexico and Canada with respect to the average number of per capita terminals in all three countries.

Rapid change in the payment dynamics in Mexico is pictured in Figure 4. We can see that the cash to cards ratio decreased abruptly in Mexico meanwhile the change was milder in the US and Canada, and the payment technology (represented by POS per capita) increased about six times faster in Mexico than in the US and Canada. We resume the growth rates of cash to cards ratios and POS per capita in Table 1. We attribute changes in Mexico's cash to cards ratio to the NAFTA and its effects on technology development mainly through payment technology diffusion.

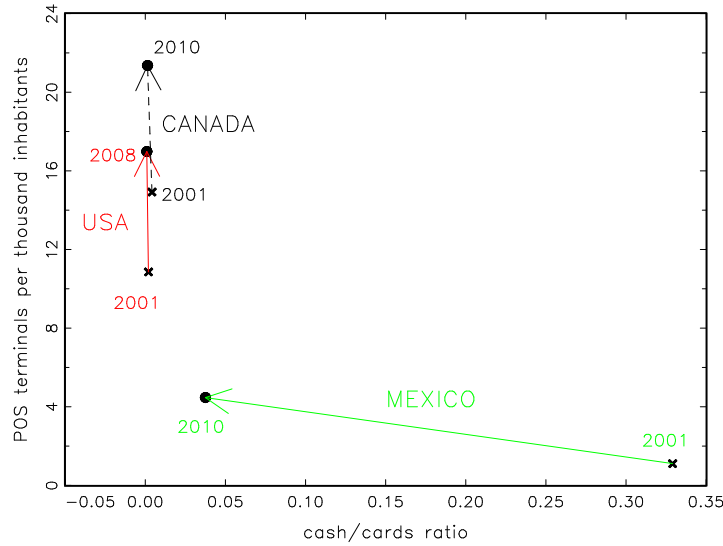


Figure 4: Change in the cash to cards ratio and payment technology level (number of POS terminals per thousand inhabitants) between 2001 (×) and 2010 (•) (2008 in the US) in the US, Mexico and Canada.

Country	Growth rate of cash/cards ratio between 2001 and 2010 [%]	Growth rate of POS per capita between 2001 and 2010 [%]
Mexico	-88	302
USA	-54	56
Canada	-66	43

Table 1: Change in the cash to cards ratio and POS terminals per capita in Mexico, USA and Canada between 2001 and 2010 (2008 in the US).

We perform our analysis in the time period 2001-2010 in a theoretical setup based on the approach of Ireland (1994) and Hromcová (2008). These models predict a switch towards electronic payments due to economic growth and/or technology development which depends on economic growth. Mexico’s average annual growth rate was very low, in the range of 0,5% per year, or negative in the period before and during the start of the operation of NAFTA. Such low growth rate would not explain the fast switch towards electronic means of payment observed in the data after 2001.

We state the model for two kinds of economies: a more developed and a less developed country which at certain moment of time open to each other and payment technology is allowed to flow between them. We calibrate the model to the US and Mexico. We compare the evolution of cash to cards ratio with technology spillovers from the US to Mexico and without it. We find that the increase in technology development due to the technology diffusion from the more developed country helps explain the increase in the usage of electronic payment instruments and an increase of cash to cards ratio. The fact that the less developed country opens may lead to welfare gains, as better technology means cheaper intermediation services and better distribution of resources.

The remainder of the paper is organized as follows. The model for less and more developed country and their main properties using analytical tools are stated in section 2. In Section 3 we calibrate the two groups of countries. In section 4 we discuss the behavior in the transition and the reaction of the economy to changes in different parameters. Final conclusions are summarized in section 5.

2 Model

We consider two economies which are initially closed. They differ in the initial level of development. Consumers in both economies can use two payment instruments, cash and electronic transactions. The choice of the payment method at a particular moment of time depends on the trade-off between the opportunity cost of holding money and the cost of electronic transactions. The existing payment technology depends on the level of capital which represents the achieved

technology level in a sense of learning-by-doing model, Barro and Sala-i-Martin (1995). Level of development is related to the level of capital. After the trade agreement comes to force, economies begin to open and there will be spillovers of the payment technology from the more developed country towards the less developed one. Taking into account that the learning-by-doing model can be reduced to an AK model, we use for our analysis the model of Ireland (1994) where we modify the cost of alternative (electronic) payment method, as in Hromcová (2008). The structure and functioning of both economies is analogous. In the following we present the model for the economy which begins with lower level of payment technology. We then generalize the model for the more developed country.

2.1 Less Developed Country

2.1.1 Household Problem

The economy consists of a large number of infinitely lived households. They all have identical preferences, production and trade opportunities. Households inhabit the following environment: they face continuum of spatially separated markets, which are indexed by $j \in [0, 1]$. All households live in market 0, and the index j indicates the distance from home. In each market j a distinct perishable good is produced and sold in every period. Goods are thus indexed by j , which corresponds to the market of both production and trade. The representative household has the preferences given by the utility function

$$\sum_{t=0}^{\infty} \beta^t \int_0^1 \frac{c_t(j)^{1-\theta} - 1}{1-\theta} dj \quad (1)$$

where $c_t(j)$ is defined as the consumption at period t of the good produced in market j , $\theta > 0$ is the inverse of the elasticity of intertemporal substitution and β is the discount factor.

The production and trade is like in Lucas and Stokey (1983). Each household is composed of a worker-shopper pair.

Prior to any trading government fixes the gross nominal interest rate R to be constant in all periods. We will assume that $R > 1$. Agents enter the period t with certain amount of monetary balances Z_t and the debt B_t , carried over from the previous period, and the capital stock k_t . A representative worker decides to produce on any of the markets j via the net production function

$$y_t = Ak_t \quad (2)$$

where A is the net productivity of capital.²

²Thanks to the AK technology, we can write the net production function as

$$y_t = (A' + 1 - \delta) k_t.$$

It corresponds the one defined in the equation (2), where A' is the marginal productivity and δ is the depreciation of capital.

First, the goods market opens and consumption takes place. Worker stays at the market j during the whole period. Shopper visits various markets to acquire consumption goods carrying all the monetary balances of the household.

Two ways of acquiring consumption goods are allowed: using money or electronic payments. All goods purchased with government issued money will be referred to as cash goods. Goods purchased via electronic payments will be referred to as electronic goods.

Nominal monetary balances Z_t can be used to buy goods in some of the markets indexed by j . Cash purchases are subject to the liquidity constraint

$$\int_0^1 [1 - \xi_t(j)] c_t(j) dj \leq \frac{Z_t}{p_t}, \quad (3)$$

where $\xi_t(j) = 0$ if a good is purchased on market j with cash, or $\xi_t(j) = 1$ if a good is purchased on market j via an electronic payment and p_t is the price level.

As we have said, agents can use an electronic payment to pay for the consumption. The financial intermediary enables electronic payments at a cost $\gamma_t(j)$ that is given for each market j and period t . The part of output that is not consumed is devoted to the investment into capital. After the goods market closes, the monetary holdings of agents are augmented by a lump sum transfer X_t from the government. The amount X_t is endogenously determined in the system according to the given nominal interest rate, so that the money demand is totally satisfied. As the next step the securities market opens. During the securities trading session households choose their currency holdings Z_{t+1} . They also purchase (or issue) one-period nominally denominated pure discount bonds paying B_{t+1} units of money at period $t + 1$ while they cost $\frac{B_{t+1}}{R}$ units of money at period t . Bonds are in zero net supply. The budget constraint agents are facing can be written

$$\int_0^1 [c_t(j) + \xi_t(j)\gamma_t(j)] dj + k_{t+1} + \frac{Z_{t+1}}{p_t} + \frac{B_{t+1}}{Rp_t} \leq Ak_t + \frac{Z_t}{p_t} + \frac{B_t}{p_t} + \frac{X_t}{p_t}. \quad (4)$$

2.1.2 Financial Intermediation

We take the description of the specification of the intermediation cost from Ireland (1994) and Hromcová (2008). Following Ireland (1994), in order to purchase consumption goods without cash, some resources must be devoted to making the non-cash payment itself available, checking the identity of the buyer and his ability to pay. When the shopper is far away from home (market zero) the communication becomes more difficult, and we assume that the payment to the intermediary increases with j . Following Hromcová (2008), the real payment made to the intermediary is characterized by a function that fulfills properties found in some empirical studies: the intermediation cost is lower in richer countries and the cost elasticity is close to zero (which motivates the proportional intermediation cost).

Intermediation function is defined as

$$\gamma_t(j) = \left(\frac{j}{1-j} \right) \left[\frac{c_t(j)}{\omega_t} \right] \quad (5)$$

where ω_t represents the payment technology. Payment technology is better when the technology level improves, i.e. when capital increases. We assume the payment technology to be equal to the level of capital in the economy,

$$\omega_t = k_t. \quad (6)$$

The time dependent part of the intermediation cost embodies the fact that higher purchase means that more importance should be given to checking the ability of the buyer to pay, thus its proportionality to consumption purchases.³ It also reflects the development of new technologies in the process of learning-by-doing and resulting more sophisticated payment system and cheaper intermediation cost.

2.1.3 Payment Choice

Consider a given level of payment technology ω_t . Given that $\gamma_t(j) = \infty$, whenever $R > 1$, households will choose cash goods in markets far away from home (market 0) and electronic goods in markets close to home. Therefore, there will exist at each time t a market with cutoff index $s_t \in (0, 1)$, such that in all markets with indexes $j < s_t$ consumers will use electronic payments and in all markets with indexes $j \geq s_t$ consumers will use cash to acquire the consumption goods. In the cutoff market consumers are indifferent between using cash or electronic payments. We arbitrarily assume that cash will be used at the cutoff market.

Define

$$c_t(j) = \begin{cases} c_t^0(j) & \text{when } \xi_t(j) = 0, \\ c_t^1(j) & \text{when } \xi_t(j) = 1. \end{cases}$$

The functions $c_t^0(j)$ and $c_t^1(j)$ characterize the cash and electronic consumption per market j , respectively. We can then write the utility function, budget and cash-in-advance constraint in a following way

$$\sum_{t=1}^{\infty} \beta^t \left[\int_0^{s_t} \frac{c_t^1(j)^{1-\theta} - 1}{1-\theta} dj + \int_{s_t}^1 \frac{c_t^0(j)^{1-\theta} - 1}{1-\theta} dj \right], \quad (7)$$

$$\begin{aligned} \int_0^{s_t} [c_t^1(j) + \gamma_t(j)] dj + \int_{s_t}^1 c_t^0(j) dj + k_{t+1} + \frac{Z_{t+1}}{p_t} + \frac{B_{t+1}}{Rp_t} \\ \leq Ak_t + \frac{Z_t}{p_t} + \frac{B_t}{p_t} + \frac{X_t}{p_t} \end{aligned} \quad (8)$$

³Proportional intermediation cost, apart from being more realistic, as argued in Hromcová (2008), allows for very elegant numerical solution.

and

$$\int_{s_t}^1 c_t^0(j) dj \leq \frac{Z_t}{p_t}. \quad (9)$$

2.1.4 Equilibrium

Definition: Given the set of initial conditions k_1, Z_1, B_1 and the nominal interest rate R , the equilibrium consists of sequences $\{c_t^0(j), c_t^1(j), k_{t+1}, Z_{t+1}, B_{t+1}, s_t, \omega_t, X_t, p_t\}_{t=1}^\infty$ such that

- (a) a representative household is maximizing the discounted utility (7) subject to the budget constraint (8) and the cash-in-advance constraint (9), choosing the sequences $\{c_t^0(j), c_t^1(j), k_{t+1}, Z_{t+1}, B_{t+1}, s_t, \omega_t\}_{t=1}^\infty$,
- (b) markets for goods, money and bonds clear in every period,

$$Ak_t = \int_{s_t}^1 c_t^0(j) dj + \int_0^{s_t} c_t^1(j) dj + \int_0^{s_t} \gamma_t(j) dj + k_{t+1}. \quad (10)$$

$$Z_{t+1} = Z_t + X_t, \quad (11)$$

$$B_{t+1} = 0. \quad (12)$$

- (c) payment technology depends on the level of capital, (6).

Let λ_t and η_t be the non-negative Lagrange multipliers associated with the budget constrain (8) and the cash-in-advance constraints (9), respectively. The equations that characterize the equilibrium are the above mentioned market clearing conditions (10), (11), (12) and the first order conditions on consumption, capital, nominal balances, nominal bonds and cutoff index, respectively,

$$c_t^0(j)^{-\theta} = \lambda_t + \eta_t, \quad (13)$$

$$c_t^1(j)^{-\theta} = \lambda_t, \quad (14)$$

$$\lambda_t = \beta \lambda_{t+1} A, \quad (15)$$

$$\frac{\lambda_t}{p_t} = \beta \frac{\lambda_{t+1} + \eta_{t+1}}{p_{t+1}}, \quad (16)$$

$$\frac{\lambda_t}{p_t} = \beta R \frac{\lambda_{t+1}}{p_{t+1}}, \quad (17)$$

$$\frac{c_t^0(s_t)^{1-\theta} - 1}{1-\theta} - \frac{c_t^1(s_t)^{1-\theta} - 1}{1-\theta} = -\lambda_t [c_t^1(s_t) + \gamma_t(s_t)] + (\lambda_t + \eta_t) c_t^0(s_t). \quad (18)$$

Using (13), (14), (16) and (17), we can rewrite the first order conditions on both consumptions as follows:

$$c_t^0(j)^{-\theta} = R \lambda_t, \quad (19)$$

$$c_t^1(j)^{-\theta} = \lambda_t. \quad (20)$$

From the first order condition (18) we get the payment to the intermediary to be paid at the cutoff market ⁴

$$\gamma_t(s_t) = \frac{1}{\lambda_t} \left[\frac{c^1(\lambda_t)^{1-\theta} - 1}{1-\theta} - \frac{c^0(R, \lambda_t)^{1-\theta} - 1}{1-\theta} \right] + Rc^0(R, \lambda_t) - c^1(\lambda_t). \quad (21)$$

Taking into account the expressions (19), (20), and (5), the equilibrium on the goods market (10) can be rewritten as

$$Ak_t = \int_{s_t}^1 c^0(R, \lambda_t) dj + \int_0^{s_t} c^1(\lambda_t) dj + \int_0^{s_t} \frac{j}{1-j} \frac{c^1(\lambda_t)}{\omega_t} dj + k_{t+1}. \quad (22)$$

The current period output is spent between cash consumption, electronic consumption, payment to the intermediary and investment. The real monetary balances, which equal the amount of cash consumption purchased in all markets, are

$$m_t = (1 - s_t) c^0(R, \lambda_t), \quad (23)$$

where

$$m_t = \frac{Z_t}{p_t}. \quad (24)$$

The consumption via financial intermediaries, which equal the amount of electronic consumption purchased in all markets, is

$$e_t = s_t c^1(\lambda_t). \quad (25)$$

The payment to the intermediary is

$$g_t = \{-s_t - \ln[1 - s_t]\} \frac{c^1(\lambda_t)}{\omega_t}, \quad (26)$$

which represents the resources paid to the intermediary in all markets, where the term in the brackets is obtained solving the third integral in the equation (22). Considering that the intermediation cost is defined by the function (5), we can write the cutoff index combining (5) and (21) in the following form

$$s_t = s(R, \omega_t) = \frac{\phi(R)}{\frac{1}{\omega_t} + \phi(R)} \quad (27)$$

where

$$\phi(R) = \begin{cases} \ln R & \text{for } \theta = 1, \\ \frac{\theta}{1-\theta} \left(1 - \frac{1}{R^{\frac{1-\theta}{\theta}}} \right) & \text{for } \theta \neq 1. \end{cases} \quad (28)$$

⁴The initial level of the Lagrange multiplier on the budget constraint depends on the monetary policy, $\lambda_t = \lambda_t(R)$, but for simplicity we only write λ_t .

The cutoff index describes the proportion of markets in which agents employ services of the intermediary. From (15) we can get the evolution of the marginal utility of consumption, we can see it is constant over time. The ratio of cash to electronic consumption can be expressed as

$$\frac{m_t}{e_t} = \frac{1}{\omega_t \phi(R) R^{\frac{1}{\theta}}}. \quad (29)$$

The payment technology level and the monetary policy affect the composition of the payment methods.

2.1.5 Asymptotic Balanced Growth Path: Analytical Solution

If the learning-by-doing process leads to an increase in the level of capital, and the consequent level of payment technology, $\omega_t \rightarrow \infty$, the equation (27) implies that the cutoff index approaches unity, $s(R, \omega_t) \rightarrow 1$. That means that cash is less and less employed when the economy has more sophisticated payment system, and the ratio of cash to electronic purchases decreases to 0, see equation (29).

In the following proposition we resume the results concerning the long run growth rates of several variables.

Proposition 1 *On the asymptotic balanced growth path the cash consumption and the payment for the electronic transactions do not grow. The economy and the electronic transactions grow at the rate $(\beta A)^{\frac{1}{\theta}}$.*

Proof. From (15), (20), (25) and (27) we get that the electronic consumption grows at the rate $\left(\frac{\lambda_t}{\lambda_{t+1}}\right)^{\frac{1}{\theta}}$. From (19), (23), (27) and (26) we see that the real balances and the payment to the intermediary do not grow in the long run. The goods market equilibrium (22) rewritten using (23), (25) and (26),

$$Ak_t = m_t + e_t + g_t + k_{t+1}$$

implies that the electronic consumption grows like capital. Capital grows at the same rate as output. ■

2.1.6 Transitional Dynamics: Numerical Solution

In order to characterize the dynamics we rewrite the equilibrium equations. We define

$$\hat{m}_t = m_t \lambda_t^{\frac{1}{\theta}}, \quad \hat{e}_t = e_t \lambda_t^{\frac{1}{\theta}}, \quad \hat{g}_t = g_t \lambda_t^{\frac{1}{\theta}}, \quad (30)$$

and the sum of transformed expenses on consumption can be written as

$$\hat{f}(R, \omega_t) = \hat{m}_t(R, \omega_t) + \hat{e}_t(R, \omega_t) + \hat{g}_t(R, \omega_t). \quad (31)$$

The goods market equilibrium (22) implies that it is in fact equal to

$$\hat{f}(R, \omega_t) = (Ak_t - k_{t+1}) \lambda_t^{\frac{1}{\theta}}.$$

Then we write the goods market equilibrium for two consecutive periods and get a second order difference equation for capital

$$\frac{Ak_{t+1} - k_{t+2}}{Ak_t - k_{t+1}} = (\beta A)^{\frac{1}{\theta}} \frac{\hat{f}(R, \omega_{t+1})}{\hat{f}(R, \omega_t)}. \quad (32)$$

Because we know the long run characteristics, we will use backward induction to solve the difference equation in capital (32). We assume that for some high enough level of human capital, say $k_{T+1} \approx 10^{15}$, the economy is on its balanced growth path, $\frac{k_{T+2}}{k_{T+1}} = \lim_{t \rightarrow \infty} \left(\frac{k_{t+1}}{k_t} \right) = (\beta A)^{\frac{1}{\theta}}$. Then we apply the Newton Raphson method to find k_t knowing k_{t+1} and k_{t+2} for all t . In this way we obtain a numerical policy function $k_{t+1} = \mathcal{K}(k_t, R)$. Given the initial level of capital and the policy function, the behavior of all other variables in the economy can be calculated from the equations (22)-(28).

2.2 More Developed Country

When writing the version of the model for the more developed country we use the analogous notation but in capital letters. In Table 2 we resume the notation for both countries involved.

Variable	More developed country	Less developed country
level of capital	K_t	k_t
level of payment technology	Ω_t	ω_t
total cash consumption	M_t	m_t
total electronic consumption	E_t	e_t
cutoff market index	S_t	s_t
nominal interest factor (monetary policy)	\mathbb{R}	R
parameter related to the monetary policy	$\Phi(\mathbb{R})$	$\phi(R)$
marginal utility of wealth	Λ_t	λ_t
total payment to intermediary	G_t	g_t
net marginal productivity of capital	\mathbb{A}	A
transformed sum of consumption related expenses	$\hat{F}(\mathbb{R}, \Omega_t)$	$\hat{f}(R, \omega_t)$

Table 2: Resume of the notation for both countries.

2.3 Payment Technology Spillovers

The trade agreement makes the economies gradually open to each other and the payment technology can flow between countries.⁵ We consider that after the trade agreement begins to operate, the payment technology of the less developed economy will receive a 'push' from the payment system of the more developed country. We assume that the payment technology of the less developed country is the following combination of the payment technology level achieved in both economies

$$\omega_{t+1} = \left[(\beta \mathbb{A})^{\frac{1}{\theta}} - 1 \right] [(1 - \alpha) \omega_t + \alpha \Omega_t] + \omega_t. \quad (33)$$

where $0 < \alpha \leq 1$.⁶ Recall that the level of payment technology in the more developed economy depends on its capital, $\Omega_t = K_t$. Therefore, the growth rate of the payment technology in both countries converges to the growth rate of capital in the more developed one.

3 Calibration

We calibrate our model using yearly data on Mexico and USA in the time interval close to the start of the operation of the NAFTA, 1994-2004. This calibration exercise serves us to show the behavior of the model and see that even such a simple specification can lead to a quite accurate description of the empirical behavior.

We set the inverse of the intertemporal elasticity of substitution to $\theta = 1$, and the discount factor in the utility function $\beta = 0.99$, common in both economies. Average growth rate of GDP per worker in the US is 2%, which implies $\mathbb{A} \approx 1.03$. Average nominal interest rate in the US is 3%. Monetary policy of the more developed country in the model is thus set to $R = 1.03$.⁷ Mexico's growth rate in the stated interval is 0.4%, i.e. the balanced growth path gross growth rate is 1.004, which implies $A \approx 1.014$. Monetary policy in Mexico is set to $R = 1.08$. We set the initial level of capital in the US as to match the cash to cards ratio in 1994. Initial capital in Mexico is chosen to match the gap in capital between the two countries in the initial year. The convergence parameter in (33) that fits the data is $\alpha = 0.15$.

4 Discussion of the Evolution of the Payment Choice

In our baseline model, growth in technologies lowers the intermediation cost and induces a switch from cash to electronic payments. Mexico experimented crises and periods with negative

⁵The payment technology can be view in the spirit of technology capital in McGrattan and Prescott (2009). Once the economies stop being closed, the payment technology can be operated in any location. The adoption of payment technology, however, may take time.

⁶This evolution is based on the convergence equation suggested in Lucas (2009).

⁷Average growth rate of GDP per worker in Canada in the selected interval is the same as in the US, the Bank of Canada interest rate is slightly higher, about 5%. So if we included Canada in the calibration of the developed country, the parameter values would not be affected significantly.

or very low growth rates that would not explain the switch towards electronic payments. The model for closed Mexico would predict very slow switch towards electronic payments. However, in the data we observe an intensive switch towards electronic means of payment. Here we show how the openness towards a more developed country with higher level of payment technology may explain that switch.

We simulate the evolution of cash to cards transactions in the more developed and the less developed countries over time. We assume that the trade agreement starts to operate at a given time, $t = T_{open}$, when the cash to cards ratio in Mexico steeply drops. At $t = T_{open}$ both countries open and the payment technology flows from the more developed country towards the one with lower level of capital and development. Our analysis includes several cases: a) how the strength of the spillovers in the payment technology affects the payment choice in the less developed country, b) what would be the behavior of cash/electronic consumption if the improvement of the payment technology was only due to the development of own new technologies (linked to the growth rate of the economy), c) how a combination of growth rate and spillovers modifies the evolution of the payment choice.

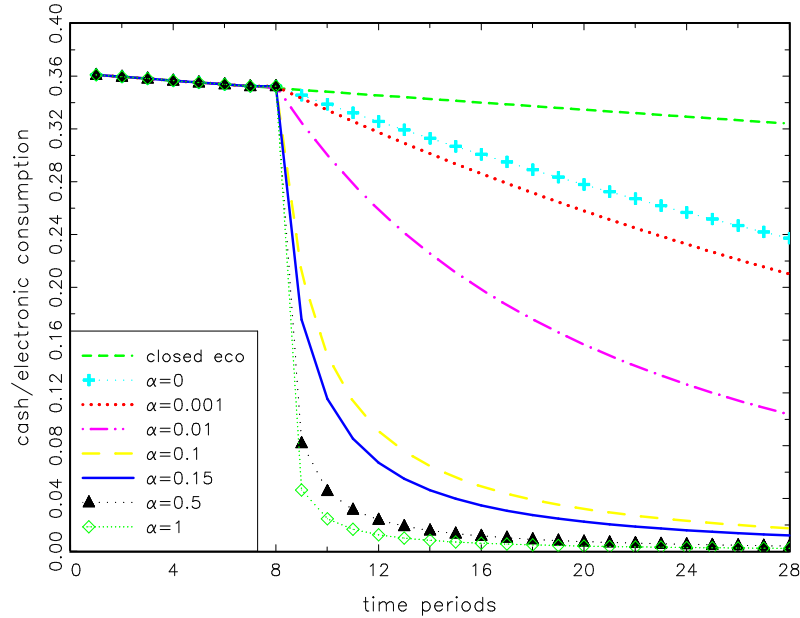


Figure 5: Evolution of the ratio between cash and electronic consumption in the model for a closed economy, and for an open economy with different force of spillovers, $\alpha = 0, 0.001, 0.01, 0.1, 0.5$ and 1 (see equation (33) for the meaning of the parameter α).

Figure 5 shows how a variation in the level of payment system spillovers changes the agents' choice. When the economy remains closed, it is the growth rate of a country that marks the pace of transformation of the payment choice. When the economy opens, the updating to the more developed payment technology makes the cash to electronic ratio converge to the one of the more developed economy. The speed of convergence is characterized by the strength of

spillovers (an increase in the parameter α means stronger spillovers and a faster convergence). In Figure 6 we plot how the growth rate of a country influences its changes in the cash to cards ratio. An increase in the less developed country's growth rate would produce a decrease in the cash to cards ratio. Figure 6 also tells us that a decrease in the cash to electronic payments ratio similar to the one observed in the data would occur if Mexico were to increase its growth rate way above 10%, an event not observed in reality.

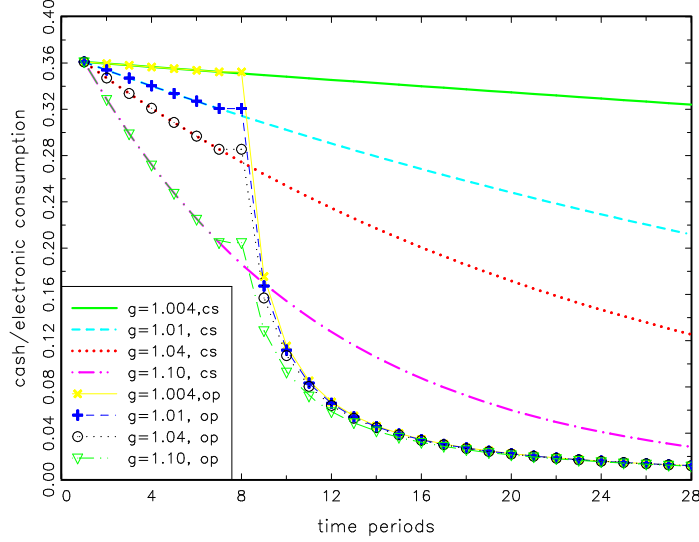


Figure 6: Evolution of the ratio between cash and electronic consumption in the model for a closed and open economy with different balanced growth path growth rates, $g = 1.004, 1.01, 1.02, 1.1$, for $\alpha = 0.15$; cs=closed, op=open.

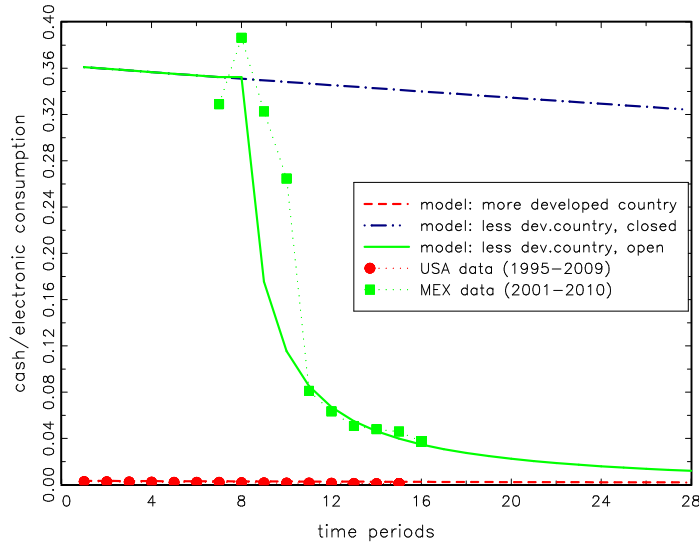


Figure 7: Evolution of the ratio between cash and electronic consumption in the less developed economy, closed and open, and the more developed economy in the model, and the comparison to the data, $T_{open} = 8$ ($year_{open} = 2002$).

Using our baseline calibration we can match the evolution of cash/electronic goods in the data of Mexico and the US, see Figure 7. After opening, technology flows from the more developed country to the less developed one. This means that the level of payment technology in the less developed country, ω_t , increases and the intermediation cost decreases, see equation (5). Cheaper intermediation cost implies that less resources are channeled towards the intermediaries, and more resources can be used for consumption. The total consumption, cash and electronic, $m_t + e_t$, in the less developed economy when open and closed is plotted in Figure 8. We thus see that welfare gains may be associated to openness and the resulting drop in cash to cards ratio.

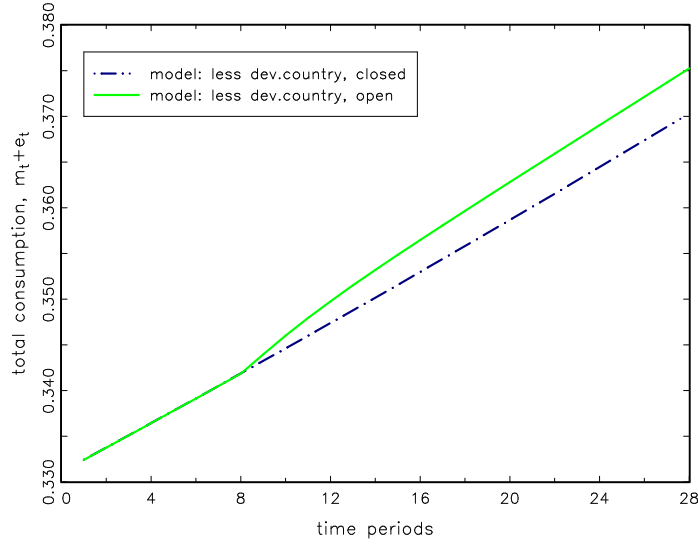


Figure 8: Evolution of total consumption, $m_t + e_t$, in the less developed economy when closed and open at $T_{open} = 8$, for the baseline calibration for Mexico.

5 Conclusions

Recent theoretical models have highlighted the relevance of trade in different economic dimensions. This paper focuses on payment systems. It investigates how technology spillovers transmit through international trade and enhance the development of payment systems instruments. In particular, the model predicts a significant drop in the usage of cash after the less developed trading partner involves fully in an open trade agreement with the developed one. Actually, the degree of convergence depends on the intensity of payment technology diffusion. The model is calibrated using data from Mexico. Further, although economic growth is considered to spur card usage as well, we show that in the case of Mexico, this was not enough to explain the increasing trend in electronic means of payments usage. We also show that reductions in intermediation costs have positive effects on consumption. Therefore, those countries who want to intensify technology spillovers should consider very seriously a trade liberalization.

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